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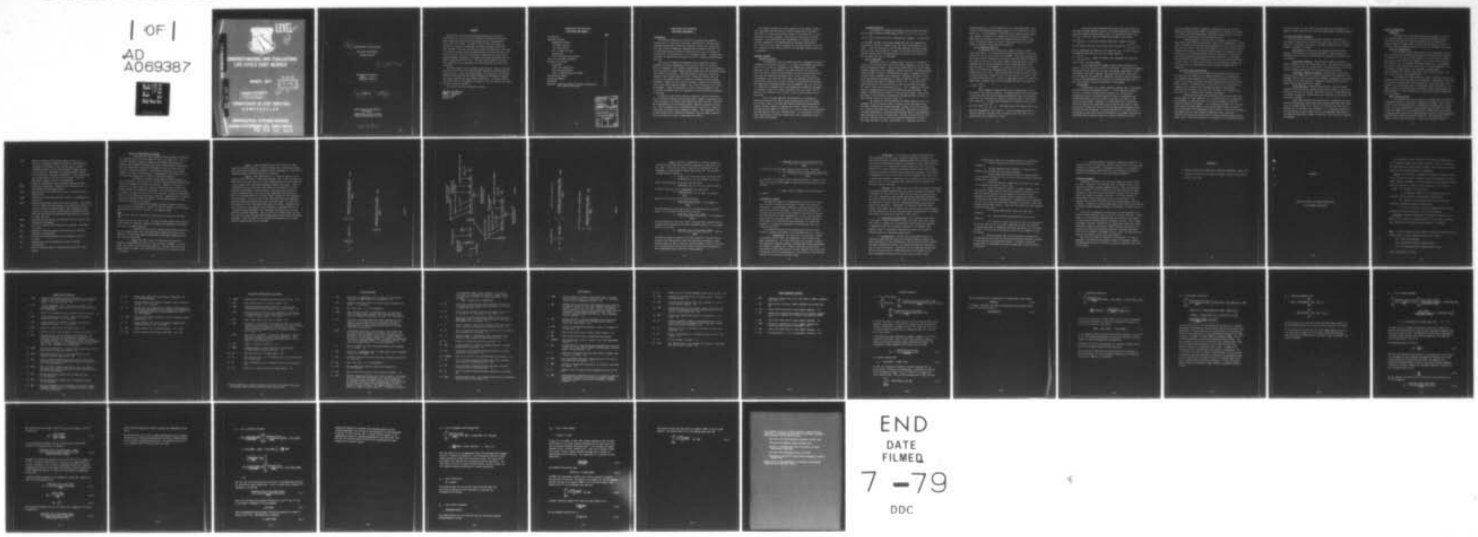

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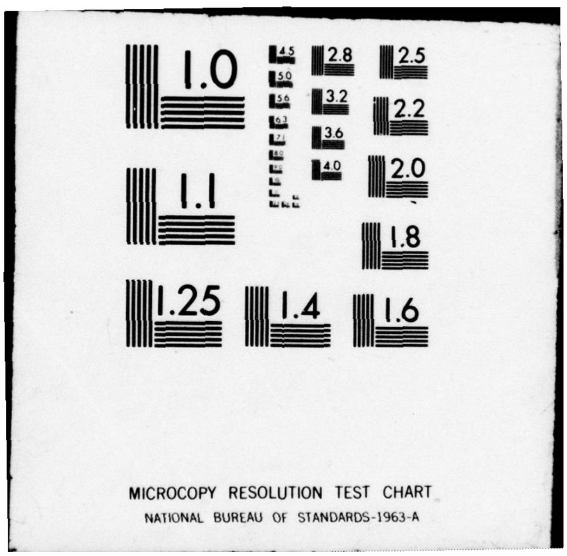
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AERONAUTICAL SYSTEMS DIVISION

UNDERSTANDING AND EVALUATING LIFE CYCLE COST MODELS

MARCH 1977

(DIRECTORATE OF COST ANALYSIS)
COMPTROLLER

AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AFB, OHIO 45433

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UNDERSTANDING AND EVALUATING

LIFE CYCLE COST MODELS.

(SECOND EDITION)

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REVISED AND UPDATED BY:

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FOREWORD

Reducing the costs of acquiring and owning future Air Force systems must be a priority system planning and acquisition objective. Many design and other acquisition program decisions significantly affect life cycle costs. In order to reduce life cycle costs, all who make or influence these design and other acquisition decisions, must consider life cycle costs and cost reduction objectives in arriving at decisions in their areas of responsibility. Because life cycle cost models are often used in the process of considering life cycle costs, program managers, engineers, procurement, and other specialists must be able to understand and use them. This guide was prepared to help Air Force personnel better understand and more effectively use life cycle cost models.

The first edition of this guide was written by Mr. John D.S. Gibson, as part of the work of the Joint AFSC/AFLC Commanders' Working Group on Life Cycle Cost. This, the second edition, is an update of the earlier edition and incorporates the latest revisions to the logistics support cost model equations and data element definitions. It further updates and revises some of the guidance contained in the first edition to reflect the most current information.

This report has been reviewed and approved.

Robert L. Zambenini

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Comptroller

UNDERSTANDING AND EVALUATING

LIFE CYCLE COST MODELS

UNDERSTANDING AND EVALUATING LIFE CYCLE COST MODELS

INTRODUCTION

The effective application of life cycle costing (LCC) generally requires use of a life cycle cost model. Historically, this has caused problems because many who should be involved in life cycle costing have felt they could not adequately comprehend the LCC models involved. This is unfortunate because learning to understand life cycle cost models is not difficult if one goes about it in a systematic manner. Understanding LCC models is important and necessary in order to properly and effectively use them.

Life cycle cost models are generally used to explicitly request, document and convey information on the life cycle cost of a system or piece of equipment. This includes preparation of life cycle cost estimates. The exact nature of models differs widely because they are tailored for almost every specific application. Some LCC models are used only to sum cost elements to get a total life cycle cost. Others not only do this, but arrive at cost element values as a function of design or other program parameters. Models are often used to estimate a contract cost objective, such as the target logistics support cost or life cycle cost, for a piece of equipment. Often the same model is used to assess equipment's life cycle cost performance after the equipment has been delivered and deployed in the field.

The material that follows has been prepared to instruct people who have not had any mathematics beyond high school algebra to understand life cycle cost models, and thereby more effectively work with them. This will be accomplished by first describing several important concepts and their use. Then an example will be discussed in which a portion of a specific life cycle cost model will be examined in detail. This examination will be made using a set of systematic procedures, which the reader should be able to use again to learn to understand other models.

The Appendix contains the entire equation for the Logistic Support Cost (LSC) Model and definitions of over 90 terms used in the model. This model is of particular interest because it and variations of it are being used on several programs. This model was developed by Hq AFLC personnel. They periodically make improvements on the model and can provide information on its demonstrated and potential applications. They can also provide computer programs and detailed instructions for its use. Questions on the nature and use of the LSC model should be directed to AFALD/XRS.

IMPORTANT CONCEPTS

Mathematical Models

A mathematical model is nothing more than a mathematical equation statement of a problem or situation. In a model the mathematical relationships of all the factors considered in the problem are clearly and explicitly shown. As an example, the model could show the total life cycle cost was the sum of the development cost plus the acquisition cost plus life time operating and support costs. This is the most basic relationship in the life cycle cost model, but sometimes becomes rather involved when between ten to twenty elements are considered individually and computed with different models, and then summed to get the total cost. It is important to remember that, while mathematical models are designed to represent situations or things occurring in the real world, they are generally very simplistic with respect to what actually happens in the real world.

One of the most important characteristics of mathematical models and something that often creates confusion when they are viewed for the first time, is the fact that familiar things are represented by symbols, letters, numbers or combinations thereof. Models become more involved when the number of variables, i.e., factors taken into consideration and affecting the total cost, becomes greater. It is essential to have a clear understanding of what all symbols mean, when attempting to learn to understand and use models.

LCC Model Structure

The process of summing cost elements to get a total life cycle cost is often expressed mathematically as LCC = $C_1 + C_2 + C_3 + C_4$, etc., or LCC = $\sum_{i=1}^{i=n} C_i$, where there are n different cost elements. To understand a cost model, one must first clearly understand what cost elements are included and how they are summed to get the total cost produced by the model. Since cost data may be used for many purposes, one cannot assume that the total value produced by a model is the total value needed for a specific purpose, until one understands the structure of the model and how the total cost value is developed.

Use of Subscripts

Subscripts, that is, a smaller letter, such as "i", generally placed to the right and lower than the variable designation (P_i) are often used in mathematical models. The purpose of subscripts is to use the same variable designation, as an example, a large P for price, for many different items that must be bought. The subscripts are used to designate which of the many items a specific price represents. Therefore, the price of the first item would be represented by a capital P subscript 1 (P_1), the price of the second item capital P subscript 2 (P_2), etc. If the price per item varied both by item type and by the year in which they are bought, the large P would have two subscripts ($P_{i,j}$). The i designating the item and the j designating the year for which the price was applicable. Any number of subscripts may be used in a life cycle cost model. Some or all may apply to each variable as appropriate, depending whether the value of that variable varies by item type, year, etc.

By convention, those developing cost models generally used i to represent the first subscript used. If there are two subscripts within the model, j might be the second subscript, k might be the next subscript, etc. However, this approach is not always used. The person who prepared the model should make it clear what each subscript means in an appropriate model description or set of instructions. However, if they have not, the user must otherwise find out what each subscript means both in terms of what varies and why it varies. Often where i = 1 represents the first

item subscripted, i = n will represent the last item subscripted. There should be some explanatory material saying n = 25 if there are 25 items, years, etc., to be considered. Subscripts tend to make the model appear very complex. However, if the subscripts are properly explained in model description material, their use becomes relatively easy to understand, and greatly reduces the length of the model equations and the number of different terms that must be defined.

Use of Summation Signs (Σ)

In mathematics the Greek letter sigma (Σ) means to sum the items that follow. It is essentially a shorthand procedure to keep from having to write out all the terms to be summed. Given time and space the same thing could be indicated by listing all items and using the familiar plus sign (+) in front of each item. Sigma is used generally to indicate summation over one or more subscripts such as those discussed in the previous section. As an example, if we were to buy one of each of ten items, all of which had a different price (P), we could use a total cost formula such as $TC = \Sigma P_i$. This indicates that to get the total price one would sum the prices of each of the n, in this case 10, "i" items. This is often written with an i = 1 below the sigma sign and an i = n above the sigma sign to indicate that it is to be summed for every item from 1 to n, such as $\sum_{i=1}^{i=n} P_i$.

Double summation signs indicated by two sigma signs ($\Sigma\Sigma$) are also used in life cycle cost models. An example would be where one wishes to calculate the total cost of buying ten different items with different prices for each item and where the price varied from year to year between year 1 and year Y. In this case the appropriate equation would be Total Cost (TC) equals $\sum_{i=1}^{i=n} \sum_{j=1}^{j=Y} P_{ij}$. Once again below each sigma should be the subscript designators i and j equals 1. Above one sigma should be i=n to indicate that TC is the sum of all n items and above the other j=Y to indicate that TC is summed over Y years.

Often two or more variables such as price (P) and quantity (Q) will have the same subscript such as i, for item designation, to indicate that both factors vary from item to item. In this case the total cost (TC) for n different types of items would be given by the formula

$TC = \sum_{i=1}^{i=n} P_i Q_i$. If the price varied by year over a period of n years, but the quantity did not, the formula would be written $TC = \sum_{i=1}^{i=n} \sum_{j=1}^{i=Y} P_{ij} Q_i$, where i designated the item and j indicated the year. If both the price and quantity varied by year the total formula would be

$TC = \sum_{i=1}^{i=n} \sum_{j=1}^{j=Y} P_{ij} Q_{ij}$. Triple and higher order summations are sometimes used in life cycle cost models.

Use of subscripts and summation signs greatly simplifies the process of writing life cycle cost model equations. Where multiple summation signs and multiple subscripts are used, they appear complicated to those not familiar with them. However, such equations indicate nothing more than the addition of several cost components, and can be easily understood as soon as one understands exactly what all the subscripts mean and over what each variable or group of variables is being summed.

Discounting

Discounting is an economic analysis technique used in evaluating the relative merits of proposed projects. Its most important property is that it considers the time value of money, i.e., in evaluating alternatives, places a different amount of weight on expenditures and savings depending on the year in which they occur, the further in the future the less weight. Therefore, to use discounting it is essential that the timing of all expenditures and savings are identified in terms of the year in which they occur, so that the appropriate weighting factor for each year can be applied. The most important fact to realize about discounting is that actual costs and savings are not changed, and that the discounted cost and savings values are artificial numbers to be used

only as a figure of merit to evaluate a proposed project, and are of no value for pricing or other budget related questions. Because of the need to discount cost and savings values, variables related thereto are often subscripted to indicate the year in which they occur.

Discounting and its use are often the subject of controversy. One issue is what interest rate should be used in the computations. Another issue is whether use of discounting is appropriate at all, since the Government does not invest in projects like business, where use of discounting to evaluate new projects is a relative standard practice. Therefore, it may be desirable to economically assess the life cycle costs of alternatives both with and without discounting to see what difference its use makes. When discounting is used the discount rate of 10% specified in DOD-I 7041.3 should be used. If other discount rates are considered more appropriate both these rates and 10% should be used in separate computations for comparison.

Use of Frequency Distributions

The detailed nature of frequency distributions and their use in life cycle cost models is too complex a subject to be included here. If a complete understanding of how a frequency distribution is used in a model is required, the subject should be pursued with the source of the model. However, for many purposes it may suffice just to know only what resources the cost model term including the frequency distribution describes, such as spares costs, and what variables, such as demand rate, unit cost, etc., influence these resource requirements.

Frequency distributions are used most often in cases where the average number of items, manhours, etc., required would not be appropriate. As an example, in some cases there is a very low demand for a mission essential reparable item spares. If the spares were bought with the usual rules based on average demand, a very limited number would be procured. This could result in the grounding of many aircraft if there was an unusually high demand rate for some unexpected temporary reason. Therefore, frequency distributions are often used to compute insurance spares requirements, where a specified probability or confidence of not grounding aircraft

for lack of parts is a more appropriate consideration in estimating the number of spares required, than long term average number of spares required.

LIFE CYCLE COST MODEL VARIABLES

Most life cycle cost models have many variables. They describe a wide range of factors which influence the total life cycle cost and are explicitly considered in the model. They may be broken out into several classes of variables including:

Cost Factors - Factors such as dollars per base maintenance manhour, which do not vary by design alternative. They are generally provided by the Air Force, and often exist as standards to be used in all cost models.

Operational Variables - Factors such as number of aircraft, number of bases, total force flying hours, etc., that describe how a system will be used rather than the system itself. They generally do not vary for different design alternatives and are provided by the Air Force.

Subsystem or Component Variables - Factors such as mean time between failure (MTBF) and unit cost which describe each subsystem of the equipment and vary from one subsystem to another, and generally from design to design for the same subsystem. Components include First Line Units (FLUs) and Shop Replaceable Units (SRUs).

System Variables - Factors which describe a specific design approach, but do not vary by subsystem, FLU or SRU or apply to the entire system, such as fuel use factors, facilities costs, etc. Some definitions of systems variables may include some system variables as cost factors and operational variables.

These model variable type breakouts are not important as long as everyone involved knows exactly what each variable means, what model input data is required because of it, and who is to provide this data for all proposed uses of the life cycle cost model. It is sometimes desirable to know how specific pieces of input data will be developed, especially if the model is being used to assess a contractor's life cycle cost reduction achievements.

SPECIFIC INSTRUCTIONS

Background

The portion of an LCC model selected for an example is part of the Logistics Support Cost (LSC) model developed by HQ AFLC. However, since most Life Cycle Cost Contract provisions will be primarily in terms of logistics support costs, a form of the LSC model is often used in structuring and implementing life cycle costing procurement provisions.

Total Cost Computations

The LSC model and most models used in LCC procurement provisions are accounting types of models, which means that the total cost produced by the model is the sum of several subtotals for specified cost elements. The LSC model has ten such cost elements: (C_1), cost of First Line Unit (FLU) spares, (C_2), on-equipment maintenance costs, (C_3), off-equipment (base shop or depot) maintenance costs, (C_4), inventory management costs, (C_5), support equipment costs, (C_6), personnel training costs, (C_7), management and technical data costs, (C_8), facilities costs, (C_9), fuel costs, and (C_{10}) spare engine costs.

Individual cost element models are used to calculate either total element costs or the annual costs for each element. Some element total costs can be directly added to get their contribution to the total costs. The elements, for which annual costs are calculated, must be multiplied by the number of years of operation being considered, to get a total element cost before adding it to other element costs to get the total cost produced by the entire model.

Model Term Definitions

The terms defined below are used in the example used to illustrate a systematic approach to learning to understand LCC models. Each term of a model should be understood prior to studying the equations which use the terms. It is the responsibility of those developing the model to provide a clear and complete list of term definitions. Model users should insist on being provided a good set of term definitions as well as other appropriate model description and use instruction material. The terms used in the example which is shown in Figures 1, 2 and 3 are defined as follows:

STK_i	- Number of spares of the "i"th FLU (First Line Unit, i.e., the level of assembly removed for repair on the flightline) required for each base to fill the base repair pipeline including a safety stock to protect against random fluctuations in demand. This number is calculated using a number of variables and a frequency distribution. These computations are not described in this set of instructions. They are described on pages 10 and 11 of the Appendix.
M	- Number of intermediate repair locations (operating bases).
PFFH	- Peak Force Flying Hours - expected fleet flying hours for one month during the peak usage period.
TFFH	- Expected Total Force Flying Hours over the Program Inventory Usage Period.
COND	- Fraction of removed FLUs expected to result in condemnation at base level.
DRCT	- Weighted Average Depot Repair Cycle Time in months. The elapsed time for a NRTS item from removal of the failed item until it is returned to depot serviceable stock. This includes the time required for base-to-depot transportation and handling and the shop flow time within the specialized repair activity required to repair the item.
MTBF	- Mean Time Between Failures in operating hours of the FLU in the operational environment.
NRTS	- Fraction of removed FLUs expected to be returned to the depot for repair.
QPA	- Quantity of like FLUs within a system such as an aircraft. (Quantity per Application)
RIP	- Fraction of FLU failures which can be repaired in place or on line.
UC	- Expected unit cost of the FLU at the time of initial provisioning.
UF	- Ratio of operating hours to flying hours for the FLU. (Use Factor)

Steps to Understanding LCC Models

LCC models will vary somewhat in what specific cost elements are included and how they are summed to arrive at a total cost. They may vary even more with respect to specific cost element model equations. However, the procedures outlined below can be used to learn to understand and use a wide range of different LCC models of the type most likely to be used in contract provisions. The equation selected for this example computes the cost of all FLU spares by computing the cost of each type of FLU spare and summing over all types of FLU spares required.

FLU spares can range from switches to entire navigation or other subsystems. They may cost up to several hundred thousand dollars each. They may be repaired in place on the aircraft. However, if a failure is involved, it is more likely that they are removed from the aircraft and another similar FLU immediately installed. Low cost FLUs may be discarded at failure. However, as the cost of a FLU increases, so does the likelihood that it will be repaired and returned to service. However, even if repaired, spares are required to keep the system in service while the FLU is being repaired on the base or at a depot.

The FLU spares cost element equation is shown in Figure 1. The second term of equation C_1 computes the cost of spares to fill the supply pipeline from the field to the depot. The summation sign

$$\sum_{i=1}^{i=n}$$

indicates that the total depot spares costs are the sum of the depot spares costs for each type of FLU. The depot pipeline spares model equation will be used to illustrate systematic procedures for learning to understand life cycle cost model equations.

To understand what this and similar model equations mean and how they compute costs, both experienced model analysts and those using a model for the first time should systematically study model equations using the steps outlined below:

<u>Step 1</u>: The first step is to write out the equation of interest, leaving plenty of room for notes, as shown in Figure 1. In some cases, this might be the entire model equation. In other cases involving larger models, it might be the equation for only one, or a portion of one, cost element.

Step 2: Write out definitions of each term in the model equation as shown in Figure 2. While this seems like a relatively mundane step, even the most experienced analysts find it necessary to do just this to understand models with which they are not familiar.

Step 3: Label model parts (i.e., group of factors) of the equation which have easy to understand meanings. This is done to reduce the difficulty of the next step and to better understand how the model develops a total element cost value from subordinate element cost values. Figure 3 illustrates how the total spares requirement can be factored into three individual requirements for base pipeline, depot pipeline and spares to replace condemned items. This may be done immediately after finishing Step 2 if accomplishing Step 2 provides enough insight into the meanings of the model parts. If not, it can be done after Step 4 has been completed. Some who develop LCC models always label the model parts. By doing this, they make use of their LCC models much easier for others. Labeling parts of the model is a very logical step in learning to understand models, in that model builders generally start with model part definitions and then construct the model equations. Step 3 is just the reverse action and lets the user next follow the same model building logic process used by the model developer. From this point on the illustration addresses only the depot pipeline spares portion of the LSC model.

$$C_1 = M \sum_{i=1}^{N} (STK_i)(UC_i) + \sum_{i=1}^{N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT)}{MTBF_i} (UC_i)$$

$$+ \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{MTBF_i} (UC_i)$$

FIGURE 1

$$C_1 = \underbrace{M}_{\text{Nr of Bases}} \overbrace{\sum_{i=1}^{N}}^{\substack{\text{Sum over each}\\ \text{type of FLU,}\\ \text{N types}}} \overbrace{(STK_i)}^{\text{Base Stock Level}} \overbrace{(UC_i)}^{\substack{\text{Unit}\\ \text{Cost}}} + \underbrace{\sum_{i=1}^{N}}_{\text{Sum over each of N FLUs}} \frac{\overbrace{(PFFH)}^{\text{Peak Force Flying Hours}} \overbrace{(QPA_i)}^{\text{Quantity Per Aircraft}} \overbrace{(UF_i)}^{\text{Use Factor}} \overbrace{(1-RIP_i)}^{\substack{\text{Fraction of Failures}\\ \text{Repaired in Place}}} \overbrace{(NRTS_i)}^{\substack{\text{Fraction of}\\ \text{Removals Sent}\\ \text{to Depot}}} \overbrace{(DRCT)}^{\text{Average Depot Repair Cycle Time}}}{\underbrace{MTBF_i}_{\substack{\text{Mean Operating Time}\\ \text{Between Failures}}}} \overbrace{(UC_i)}^{\text{Unit Cost}}$$

$$+ \sum_{i=1}^{N} \frac{\overbrace{(TFFH)}^{\text{Total Force Flying Hours}} \overbrace{(QPA_i)}^{\text{Quantity Per Aircraft}} \overbrace{(UF_i)}^{\text{Use Factor}} \overbrace{(1-RIP_i)}^{\substack{\text{Fraction Repaired}\\ \text{In Place}}} \overbrace{(COND_i)}^{\text{Fraction of Removed Items Condemned}}}{\underbrace{MTBF_i}_{\substack{\text{Mean Operating Time}\\ \text{Between Failures}}}} \overbrace{(UC_i)}^{\text{Unit Cost}}$$

FIGURE 2

Base Spares Cost

Depot Pipeline Spares Costs

$$C_1 = M \sum_{i=1}^{N} (STK_i)(UC_i) + \sum_{i=1}^{N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT)}{MTBF_i} (UC_i)$$

Cost of Spares to Replace Condemned Items

$$+ \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{MTBF_i} (UC_i)$$

FIGURE 3

Step 4: Derive the definition of the whole equation by starting with one term and successively combining one additional term at a time. After each new term is combined, the meaning of the new combination of terms should be defined and written out. The procedure is demonstrated as follows:

a. (PFFH) is the peak force flying hours per month.

b. $(PFFH)(QPA_i)$ is the total number of hours all FLUs of this type will be flying in the peak month.

c. $(PFFH)(QPA_i)(UF_i)$ is the total operating hours all FLU of this type will be operating in the peak month.

d. $\dfrac{(PFFH)(QPA_i)(UF_i)}{MTBF_i}$ is the number of failures expected of this type of FLU in the peak month.

e. $\dfrac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i}$ is the number of failures expected of this type of FLU in the peak month not repaired in place, i.e., the number removed from the aircraft.

f. $\dfrac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)}{MTBF_i}$ is the number of failures expected of this type of FLU in the peak month removed from the aircraft and not repaired at the base intermediate shop, i.e., the number returned to the depot.

g. $\dfrac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT)}{MTBF_i}$ This is the expected number of spares of this type required in the peak flying period so that provisions are made that have spares available to keep aircraft ready, in spite of the fact that this number of FLUs of this type are not available for service due to their failure and non-availability for a specified period of time while being repaired.

$$\text{h.}\quad \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT)\,(UC_i)}{MTBF_i}$$

is the cost of all the depot pipeline spares of type i required.

$$\text{i.}\quad \sum_{i=1}^{i=N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT)\,(UC_i)}{MTBF_i}$$

is the total cost of depot pipeline FLU spares for all N types of FLUs, where N is some specified number of FLUs for which input data has been provided.

j. Repeat steps 1 through 4 for each equation in the model.

EVALUATING LCC MODELS

One important reason for understanding a life cycle cost model is to be able to evaluate the adequacy of a model for a specific application. All mathematical models are crude abstractions of the real world activities they model. Since they do not consider all pertinent factors, they may be well suited to some applications and virtually useless for other applications. A life cycle cost model must contain the variables needed to adequately describe important differences in the alternatives being evaluated or to assess the success of a contractor in meeting or surpassing life cycle cost reduction objectives.

In assessing LCC models five important model characteristics should be examined with respect to the intended model use. They are:

a. Completeness: The life cycle cost model must include all elements of life cycle cost appropriate to the decision issue under consideration. If a total life cycle cost estimate is needed for planning or budgetary purposes, the model must include essentially all elements of program cost. However, where the decision under consideration affects some but not all cost elements, only those costs affected may need to be considered in a life cycle cost model used for analysis of that particular decision issue.

b. Sensitivity: To be useful for design trade studies and other decisions, the life cycle cost model used must be sensitive to the specific design or program parameters under study, in order to resolve life cycle cost differences among the alternatives. While this should be very obvious, it is a significant problem because most life cycle cost models do not include variables describing the many design and performance parameters associated with Air Force systems and equipments. This problem is aggrevated by the fact that most Air Force equipments have unique sets of design and performance characteristics, dictating the need for different models if life cycle cost design trade studies are to be conducted for different types of equipment.

c. Validity: The validity of a life cycle cost model is a measure of how well the model represents the real-world environment in question. This is paramount if a life cycle cost model is to be used to compute the life cycle cost differences between design alternatives,and these differences are used as a basis for decisions. Given the model the analyst must verify the input data to assure that the computed model output costs are both logical and consistent. Furthermore, in using life cycle cost model results, some judgment may be required with respect to how valid estimated cost differences are, and just how much weight one should give to estimated life cycle cost differences relative to other factors.

d. Availability of Input Data: For a life cycle cost model to be useful, it must be feasible to obtain accurate input data. Some life cycle cost models are of questionable value because good estimates of important input factors cannot be obtained, or if obtained from vendors, cannot be validated by Government personnel as true and an equitable basis for comparisons among vendors.

e. Documentation: The fact that considerable latitude is allowed in conducting life cycle cost analysis studies, dictates that model descriptions be well documented so the work can be quickly reviewed and easily understood by others. All analysis methods and assumptions must be clearly documented. Assumptions are very important because they may be very questionable for some applications of the model and can have a tremendous influence on the total life cycle cost results.

In assessing the model, the following steps may be appropriate:

a. Clearly understand the use for which the model is intended.

b. Identify important model variables or characteristics needed to use the model for the purpose intended.

c. Clearly understand the model using the steps described in the Specific Instructions section and any other procedures considered appropriate and necessary.

d. Assess the model for completeness and sensitivity using the information developed in steps b and c.

e. Assess the model for validity. However, judgment will be required to balance off the fact that no models are perfect and yet many can provide valuable decision guidance for specific issues. Assessing the validity of the model should be done more in terms of looking for possible model improvements, or assessing how much confidence one can have in the cost differences indicated by the model, rather than finding possible model defects. Life cycle cost models can lack necessary validity in three ways:

(1) Provide unjustifiably large life cycle cost difference.

(2) Overlook valid and significant life cycle cost difference.

(3) Reverse the order of valid life cycle cost differences.

The second type of error is the most common and can best be eliminated by assuring the model is adequately sensitive and complete for the purpose intended. The first and third types of errors are not common, but must be avoided.

f. Review the model input data requirements, determining who can and should provide what data and assessing whether adequately accurate or valid data can be provided when needed. In addition, plans and capabilities for validating contractor prepared model input data should be assessed.

g. Determine whether the model is adequately documented. If one had to rely on a significant amount of direct contact with the model developer or other analyst to understand the model, it is probably not adequately documented, and difficulties can be expected in getting others to use the model in a timely and effective manner.

CONCLUDING COMMENTS

Learning to understand life cycle cost models may seem difficult at first. However, it is relatively easy, if adequate time is taken, using the systematic approach suggested herein. Once one understands most of a model, it is not difficult to get some help from the model developer or other life cycle cost analyst to master the total model and to get answers to specific questions. It is very difficult to beneficially discuss a model and its use, if all parties to the discussion do not know the definitions of the model terms or the cost elements. Therefore, one should understand as many model term definitions as possible before becoming involved in discussions of a model and its use.

Life cycle cost models are being used in increasing numbers as a basis for source selection and as a part of contract provisions. Therefore, it is of the utmost importance that all involved in any aspect of these activities understand the LCC models involved. This includes: procurement personnel, responsible for preparing or executing contract provisions; technical specialists, validating model input data; cost analysts and others developing and using cost estimates made using life cycle cost models; and managers and all others, who made decisions based on the results of life cycle cost analysis.

The entire LSC model is described in the Appendix. If time is available, the reader should attempt to apply the systematic methods discussed herein to test his ability to learn to understand other parts of this model.

References

1. Logistics Support Cost Model Users' Handbook, AFALD/XRS, August 1976.

2. Analysis of Available Life Cycle Cost Models and Their Applications, ASD/ACL, June 1976.

APPENDIX

LOGISTICS SUPPORT COST MODEL EQUATIONS AND

DATA ELEMENTS DEFINITIONS

The following is a brief discussion of the general characteristics of the Logistical Support Cost Model. This description is presented to help familiarize the reader with this model in order that he may better understand the rationale behind its composition.

Purpose: The LSC Model is designed to estimate the expected support costs that may be incurred by adopting a particular design for a given weapon system or equipment. The model compares and discriminates between design alternatives in terms of relative support cost differences.

Uses: The LSC Model can be applied to:

(1) determine an estimate of the logistics support cost difference between different proposed design configurations.

(2) establish a cost baseline for use with contractual commitments regarding operational support, and

(3) use as a decision aid in discriminating between design alternatives during prototyping or full-scale development.

Tailoring: Specific tailoring may be required to modify the LSC Model to better express a certain situation. In so doing, the analyst may eliminate, add or redefine certain equations or variables.

NOTE: The data elements have been coded to indicate the nature and source of model data for source selection activities as follows:

(C) - Contractor-furnished

(S) - Government-furnished, standard value *

(P) - Government-furnished, program peculiar value

* Use actual values, if known.

Weapon System Variables

1. EBO - Standard established for expected backorders -- the expected number of unfilled demands existing at the lowest echelon (bases) at any point in time. (P)

2. IMC - Initial management cost to introduce a new line item of supply (assembly or piece part) into the Air Force inventory. (S = $46.60/item)

3. M - Number of intermediate repair locations (operating bases). (P)

4. MRF - Average manhours per failure to complete off-equipment maintenance records. (S = .24 hours)

5. MRO - Average manhours per failure to complete on-equipment maintenance records. (S = .08 hours)

6. NSYS - Number of systems within the weapon system. (C)

7. OS - Fraction of total force deployed to overseas locations. (P)

8. OST - Weighted average Order and Shipping Time in months. The elapsed time between the initiation of a request for a serviceable item and its receipt by the requesting activity. For CONUS locations, S = 0.394 months (12 days) input as OSTCON. For overseas locations, S = 0.526 months (16 days) input as OSTOS. OST = (OSTCON)(1-OS) + (OSTOS)(OS).

9. PFFH - Peak Force Flying Hours -- expected fleet flying hours for one month during the peak usage period. (P)

10. PIUP - Operational service life of the weapon system in years. (Program Inventory Usage Period) (P)

11. PMB - Direct productive manhours per man per year at base level (includes "touch time", transportation time, and setup time.) (S = 1704 hours/man/year)

12. PMD - Direct productive manhours per man per year at the depot (includes "touch time", transportation time, and setup time.) (S = 1788 hours/man/year)

13. PSC - Average packing and shipping cost to CONUS locations. (S = $0.59/pound)

14. PSO - Average packing and shipping cost to overseas locations. (S = $1.22/pound)

15. RMC - Recurring management cost to maintain a line item of supply (assembly or piece part) in the wholesale inventory system. (S = $104.20/item/year)

16. SA - Annual base supply line item inventory management cost. (S = $36.59/item/year)

17. SR - Average manhours per failure to complete supply transaction records. (S = .25 hours)

18. TD - Average cost per original page of technical documentation. The average acquisition cost of one page of the reproducible source document (does not include reproduction costs.) (S = $220.00/page)

19. TFFH - Expected Total Force Flying Hours over the Program Inventory Usage Period. (P)

20. TR - Average manhours per failure to complete transportation transaction forms. (S = .16 hours)

21. TRB - Annual turnover rate for base personnel. (S = .129)

22. TRD - Annual turnover rate for depot personnel. (S = .15)

Propulsion System Peculiar Variables

1. ARBUT* - Engine Automatic Resupply and Buildup Time in months. (P)

2. BP* - Base engine repair cycle time in months. (P)

3. CMRI* - Combined Maintenance Removal Interval. Average engine operating hours between removals of the whole engine. (C)

4. CONF - Confidence factor reflecting the probability of satisfying a random demand for a whole engine from serviceable stock to replace a removed engine. (S = 0.90)

5. DP* - Depot engine repair cycle time in months. (P)

6. EOH - Average cost per overhaul of the complete engine at the depot expressed as a fraction of the engine unit cost (EUC) including labor and material consumption. Repair and stockage of reparable engine components (FLUs), considered elsewhere is not included. (C)

7. ERTS - Return rate for engines. Fraction of removed whole engines which are returned to service by base maintenance. (The complement, (1-ERTS), is the fraction which must be sent to depot for repair/overhaul.) (C)

8. EPA - Number of engines per aircraft. (C)

9. ERMH - Average manhours to remove and replace a whole engine including engine trim and runup time. (C)

10. EUC - Expected Unit Cost of a whole engine. (C)

11. FC - Fuel cost per unit. (S = $0.368/gallon for JP4; $0.427/gallon for aviation gas)

12. FR - Fuel consumption rate of one engine in units per flying hour. (C)

13. LS - Number of stockage locations for spare engines. (P)

*** Reference AFM 400-1, Volume I, Chapter 7 and Atch 1 for complete description of the Engine Pipeline (Flow Cycle) and use of these terms.**

System Variables

1. BCA - Total cost of additional items of common base shop support equipment per base required for the system. (C)

2. BAA - Available work time per man in the base shop in manhours per month. (S = 168 hours)

3. BLR - Base labor rate. (S = $13.03/manhour)

4. BMR - Base consumable material consumption rate. Includes minor items of supply (nuts, washers, rags, cleaning fluid, etc.) which are consumed during repair of items. (S = $3.19/hour)

5. BPA - Total cost of peculiar base shop support equipment per base required for the system which is not directly related to repair of specific FLUs or when the quantity required is independent of the anticipated workload (such as, overhead cranes and shop fixtures).

6. BRCT - Average Base Repair Cycle Time in months. The elapsed time for a RTS item from removal of the failed item until it is returned to base serviceable stock (Less time awaiting parts). For FLUs of the "black box" variety (e.g., avionics LRUs), the repair of which normally consists of removal and replacement of "plug-in" components (SRUs), S = 0.20 months (6 days). For other, non modular FLUs, S = 0.33 months (10 days).

7. CS - Cost of software to utilize existing Automatic Test Equipment for the system. (C)

8. DCA - Total cost of additional items of common depot support equipment required for the system. (C)

9. DAA - Available work time per man at the depot in manhours per month. (S = 168 hours)

10. DLR - Depot labor rate. (S = $18.05/manhour)

11. DMR - Same as BMR except refers to depot level maintenance. (S = $5.19/hour)

12. DPA - Same as BPA except relates to depot support equipment. (C)

13. DRCT - Weighted average Depot Repair Cycle Time in months. The elapsed time for a NRTS item from removal of the failed item until it is returned to depot serviceable stock. This includes the time required for base-to-depot transportation and handling and the shop flow time within the specialized repair activity required to repair the item. For CONUS locations, S = 1.35 months (41 days) for organic repair, S = 1.84 months (56 days)

for contractual repair, input as DRCTC. For overseas locations, S = 1.48 months (45 days) for organic repair, S = 1.97 months (60 days) for contractual repair, input as DRCTO.

DRCT = (DRCTC)(1-OS) + (DRCTO)(OS)

14. FB - Total cost of new base facilities (including utilities) to be constructed for operation and maintenance of the system, in dollars per base. (C)

15. FD - Total cost of new depot facilities (including utilities) to be constructed for maintenance of the system. (C)

16. FLA - Total cost of peculiar flight-line support equipment and additional items of common flight-line support equipment per base required for the system. (C)

17. H - Number of pages of depot level technical orders and special repair instructions required to maintain the system. (C)

18. IH - Cost of interconnecting hardware to utilize existing Automatic Test Equipment for the system. (C)

19. JJ - Number of pages of organizational and intermediate level technical orders required to maintain the system. (C)

20. N - Number of different FLUs within the system. (C)

21. SMH - Average manhours to perform a scheduled periodic or phased inspection on the system. (C)

22. SMI - Flying hour interval between scheduled periodic or phased inspection on the system. (C)

23. SYSNOUN - Name of the system -- up to 60 alphanumeric characters. (C)

24. TCB - Cost of peculiar training per man at base level including instruction and training materials. (C)

25. TCD - Cost of peculiar training per man at the depot including instruction and training materials. (C)

26. TE - Cost of peculiar training equipment required for the system. (C)

27. XSYS - System identification. The assigned five-character alphanumeric Work Unit Code of the system. (C)

FLU Variables

1. BCMH - Average manhours to perform a shop bench check, screening, and fault verification on a removed FLU prior to initiating repair action or condemning the item. (C)

2. BMC - Average cost per failure for a FLU repaired at base level for stockage and repair of lower level assemblies expressed as a fraction of the FLU unit cost (UC). This is the implicit repair disposition cost for a FLU representing labor, material consumption, and stockage/replacement of lower indenture reparable components within the FLU (e.g., shop replacement units or modules). (C)

3. BMH - Average manhours to perform intermediate-level (base shop) maintenance on a removed FLU including fault isolation, repair, and verification. (C)

4. COND - Fraction of removed FLUs expected to result in condemnation at base level. (C)

5. DMC - Same as BMC except refers to depot repair actions. (C)

6. DMH - Same as BMH except refers to depot-level maintenance.

7. FLUNOUN - Word description or name of the FLU -- up to 60 alphanumeric characters. (C)

8. IMH - Average manhours to perform corrective maintenance of the FLU in place or on line without removal including fault isolation, repair, and verification. (C)

9. K - Number of line items of peculiar shop support equipment used in repair of the FLU. (C)

10. MTBF - Mean Time Between Failures in operating hours of the FLU in the operational environment. (C)

11. NRTS - Fraction of removed FLUs expected to be returned to the depot for repair. (C)

12. PA - Number of new "P" coded reparable assemblies within the FLU. (C)

13. PAMH - Average manhours expended in place on the installed system for Preparation and Access for the FLU; for example, jacking, unbuttoning, removal of other units and hookup of support equipment. (C)

14. PP - Number of new "P" coded consumable items within the FLU. (C)

15. QPA - Quantity of like FLUs within the parent system. (Quantity per Application) (C)

16. RIP - Fraction of FLU failures which can be repaired in place or on line without removal. (C)

17. RMH - Average manhours to fault isolate, remove, and replace the FLU on the installed system and verify restoration of the system to operational status. (C)

18. RTS - Fraction of removed FLUs expected to be repaired at base level. (C)

19. SP - Number of standard (already stock-numbered) parts within the FLU which will be managed for the first time at bases where this system is deployed. (C)

20. UC - Expected unit cost of the FLU at the time of initial provisioning. (C)

21. UF - Ratio of operating hours to flying hours for the FLU. (Use Factor) (C)

22. W - FLU unit weight in pounds. (C)

23. XFLU - FLU identification. The assigned five-character alphanumeric Work Unit Code of the FLU. (C)

Support Equipment Variables

1. BUR - Combined utilization rate for all like items of support equipment—base level. (C)

2. CAB - Cost per unit of peculiar support equipment for the base shop. (C)

3. CAD - Same as CAB except refers to depot support equipment. (C)

4. COB - Annual cost to operate and maintain a unit of support equipment at base level expressed as a fraction of the unit cost (CAB). (C)

5. COD - Same as COB except refers to depot support equipment. (C)

6. DOWN - Fraction of downtime for a unit of support equipment for maintenance and calibration requirements. (C)

7. DUR - Same as BUR except refers to depot support equipment. (C)

8. XSE - SE identification — up to 20 alphanumeric characters. (C)

LSC MODEL EQUATIONS

C_1 = Cost of FLU Spares

$$= M \sum_{i=1}^{N} (STK_i)(UC_i) + \sum_{i=1}^{N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT)}{MTBF_i}(UC_i)$$

$$+ \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{MTBF_i}(UC_i)$$

The first two terms in C_i are the cost to fill the base and depot repair pipelines respectively. The quantities computed are those required to support the peak level of program activity. The third term is the cost to replace failed FLUs which will be condemned at base level over the life of the system.

In the first term, STK_i represents the number of spares of the i^{th} FLU required for each base to fill the base repair pipeline including a safety stock to protect against random fluctuations in demand. The computation of STK_i considers the mean demand rate per base,

$$\lambda_i = \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)}{(M)(MTBF_i)} \tag{1.1}$$

the weighted pipeline time

$$t_i = (RTS_i)(BRCT) + (NRTS)(OST) \tag{1.2}$$

and EBO, the established standard for expected backorders for the weapon system. Therefore, the product, $\lambda_i t_i$, represents the expected number of demands on supply for the i^{th} FLU over its average base repair pipeline time. Then, find the minimum value of STK_i such that

$$\sum_{x > STK_i} (x - STK_i)\, p(x \mid \lambda_i t_i) \leq EBO \tag{1.3}$$

where the distribution of probabilities of demand given a mean demand,

$$p(x \mid \lambda_i t_i) \tag{1.4}$$

is Poisson. Therefore, the cost to provide base repair pipeline spares of the i^{th} FLU for all bases is

$$(M)(STK_i)(UC_i) \tag{1.5}$$

C_2 = On-Equipment Maintenance

$$= \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [PAMH_i + (RIP_i)(IMH_i) + (1-RIP_i)(RMH_i)] (BLR)$$

$$+ \frac{TFFH}{SMI} (SMH)(BLR) + \boxed{\frac{(TFFH)(EPA)}{CMRI} (ERMH)(BLR)}$$

The first term in C_2 is the labor manhour cost to perform on-equipment (flight line) maintenance on FLUs due to (unscheduled) failures over the life of the system. The element,

$$PAMH_i + (RIP_i)(IMH_i) + (1-RIP_i)(RMH_i) \qquad (2.1)$$

is the weighted average on-equipment maintenance manhours per failure of the i^{th} FLU including Preparation and Access time and either in-place repair or removal and replacement as appropriate.

The second term is the labor manhour cost to perform scheduled maintenance on the complete system over the life cycle.

The third term is applicable only when dealing with a propulsion or powerplant system. It is the maintenance manhour cost to remove and replace whole engines on the aircraft.

C_3 = Off-Equipment Maintenance

$$= \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i} \Big\{ (BCMH_i)(BLR) + RTS_i[(BMH_i)(BLR + BMR) + (BMC_i)(UC_i)] + NRTS_i[(DMH_i)(DLR + DMR) + (DMC_i)(UC_i)] + [2(NRTS_i) + COND_i][(PSC)(1-OS) + (PSO)(OS)](1.35\ W_i) \Big\}$$

$$+ \boxed{\frac{(TFFH)(EPA)(1-ERTS)}{CMRI}(EOH)(EUC)}$$

The first term in C_3 is the labor manhour and material cost to perform off-equipment maintenance on failed, removed FLUs in base or depot repair facilities. All failed FLUs are first bench-checked to verify failure and then either repaired in the base intermediate maintenance shop (RTS), returned to the depot for repair (NRTS) or condemned (COND). The cost of failure verification results from expending manhours (BCMH). The cost to repair an item results from direct repair manhours (BMH or DMH) and the implied repair disposition cost to stock and repair lower indenture components and assemblies (BMC or DMC). Included is the transportation cost for NRTS FLUs and condemnation replacements. The 1.35 factor is the ratio of packed to unpacked weight. The second term is applicable only when dealing with a propulsion or powerplant system. It is the implied cost to perform overhaul of a complete engine at the depot including labor and material consumption. It does not include, however, repair and stockage of engine components considered elsewhere as FLUs.

C_4 = Inventory Management Cost

$$= [IMC + (PIUP)(RMC)] \sum_{i=1}^{N} (PA_i + PP_i + 1)$$

$$+ (M)(SA)(PIUP) \sum_{i=1}^{N} (PA_i + PP_i + SP_i + 1)$$

The first term in C_4 is the cost to enter new line items of supply into the government inventory and to manage them over the life of the system.

The second term is the life cycle base level supply management cost of these new items of supply as well as common, already-stock-numbered items which will be carried for the first time in base supply where this system is deployed.

C_5 = Cost of Support Equipment

$$= \sum_{i=1}^{N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i} \sum_{j=1}^{K} \left\{ \frac{(RTS_i)(BMH_i + BCMH_i)}{(BUR_j)(BAA)(1-DOWN_j)} [1 + (PIUP)(COB_j)]CAB_j \right.$$

$$\left. + \frac{(NRTS_i)(DMH_i)}{(DUR_j)(DAA)(1-DOWN_j)} [1 + (PIUP)(COD_j)]CAD_j \right\}$$

$$+ \quad [1 + 0.1(PIUP)][DCA + DPA + M(BCA + BPA + FLA)] \quad + \quad CS \quad + \quad IH$$

The first term in C_5 computes the quantities and costs to acquire and maintain new, peculiar items of depot and base shop support equipment (SE) utilized in repair of FLUs. The quantities are derived by considering the anticipated repair workload, the servicing capability of the shops and certain characteristics of the SE.

From queuing theory, we are given

$$\rho = \frac{\lambda}{n\mu} \leq 1 \tag{5.1}$$

where λ is the workload arrival rate, μ is the service rate of one server, n is the number of servers and ρ is the combined utilization rate of the servers which must be not greater than unity. Our objective is to calculate the minimum number of pieces of each item of support equipment ("servers") necessary to support the anticipated workload. Therefore, we must rearrange terms in (5.1):

$$n = \frac{\lambda}{\rho\mu} \tag{5.2}$$

For our purposes, the arrival rate of workload in the base shop for the i^{th} FLU is given by

$$\lambda = \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(RTS_i)}{MTBF_i} \tag{5.3}$$

The service rate for one unit of the j^{th} item of SE in support of the i^{th} FLU given by

$$\mu = \frac{(BAA)(1-DOWN_j)}{(BMH_i + BCMH_i)} \tag{5.4}$$

And the combined utilization rate, ρ, is given by the variable BUR. Therefore, by combining terms, the quantity

$$\frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(RTS_i)(BMH_i + BCMH_i)}{(MTBF_i)(BUR_j)(BAA)(1-DOWN_j)} \tag{5.5}$$

represents the fractional requirement for the j^{th} item of SE to support the i^{th} FLU. In order to compute SE costs realistically, integer quantities should be considered. All fractional requirements for SE item j should be accumulated for all FLUs in the weapon system and the result rounded up to a whole number divisible by M to give the total base-level requirement for SE item j.

A similar discussion applies to the computation of depot SE. Using (5.2) again, the depot parameters are

$$\lambda = \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)}{MTBF_i} \tag{5.6}$$

$$\mu = \frac{(DAA)(1-DOWN_j)}{DMH_i} \tag{5.7}$$

$$\rho = DUR \tag{5.8}$$

The fractional requirement for the j^{th} item of SE to support the i^{th} FLU is represented by

$$\frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DMH_i)}{(MTBF_i)(DUR_j)(DAA)(1-DOWN_j)} \tag{5.9}$$

which should be integerized to give the depot-level requirement for SE item j.

The second term in C_5 is cost to acquire and maintain items of peculiar SE which are not directly workload-related and items of common SE which must be procured in additional quantities. The arbitrary value of 0.1 is the analog of COB or COD used in the first term.

C_6 = Cost of Personnel Training

$$= \frac{[1 + (PIUP)(TRB)]\ TCB}{(PIUP)(PMB)} \left[\sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} \left\{ PAMH_i + (RIP_i)(IMH_i) \right. \right.$$

$$\left. + (1-RIP_i)[RMH_i + BCMH_i + (RTS_i)(BMH_i)] \right\} + \frac{TFFH}{SMI}(SMH)$$

$$\left. + \boxed{\frac{(TFFH)(EPA)}{CMRI}(ERMH)} \right]$$

$$+ \frac{[1 + (PIUP-1)(TRD)]\ TCD}{(PIUP)(PMD)} \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} (1-RIP_i)(NRTS_i)(DMH_i)$$

$$+ TE$$

The first and second terms in C_6 are the costs to train maintenance personnel for bases and the depot respectively. Using the second term to simplify the explanation, the quantity

$$\frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DMH_i)}{MTBF_i} \qquad (6.1)$$

gives the total depot labor manhour requirement for the i^{th} over the life of the system. Dividing (6.1) by the quantity

$$(PIUP)(PMD) \qquad (6.2)$$

gives the workload-related personnel equivalents required at the depot to support the i^{th} FLU. Multiplying by the quantity

$$1 + (PIUP-1)(TRD) \qquad (6.3)$$

reflects the turnover of personnel and essentially gives the total training requirement over the life of the system which is then multiplied by the cost to train one man, TCD. A similar exercise applies to the computation of base-level training requirements in the first term. Note that the last quantity within the first term is applicable only when dealing with a propulsion system.

C_7 = Cost of Management and Technical Data

$$= \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [MRO + (1-RIP_i)(MRF + SR + TR)] BLR$$

$$+ \frac{TFFH}{SMI} [MRO + 0.1(SR + TR)] BLR \quad + \quad TD(JJ + H)$$

The first term in C_7 is the maintenance labor cost associated with equipment failures to complete the required on- and off-equipment maintenance forms, supply transaction records and transportation forms. The second term is the similar cost associated with scheduled or periodic maintenance. The third term is the cost to acquire Technical Orders, overhaul manuals, and other special technical documentation or repair instructions.

C_8 = Cost of Facilities

$$= FD + (M)(FB)$$

This equation gives the cost of new, special base and depot real facilities (including utilities) necessary for operation and maintenance of the system.

C_9 = Cost of Fuel Consumption

$$= (TFFH)(EPA)(FR)(FC)$$

This equation gives the life cycle fuel cost for those weapon systems having propulsion systems.

C_{10} = Cost of Spare Engines

= $[(LS)(X) + Y]$ EUC

In C_{10}, X is the number of whole spare engines required to fill the base-level portion of the engine pipeline including both the base repair cycle and the Automatic Resupply and Buildup Time. Y is the number of engines required to fill the depot overhaul cycle. Both X and Y include a safety level stock to protect against pipeline shortages due to abnormal or unpredictable demand conditions. The computation of X considers the mean demand rate,

$$\frac{(PFFH)(EPA)}{(LS)(CMRI)} \tag{10.1}$$

the weighted base pipeline time,

$$(ERTS)(BP) + (1-ERTS)(ARBUT) \tag{10.2}$$

and CONF, the established confidence level factor expressed in terms of off-the-shelf availability. The product of the demand rate and the weighted pipeline time gives the argument (ARGB) of the following equation. The desired value of X is the minimum value such that

$$\sum_{n=0}^{X} \frac{(e^{-ARGB})(ARGB)^n}{n!} \geq CONF \tag{10.3}$$

A similar computation applies for Y where the mean demand rate is

$$\frac{(PFFH)(EPA)}{CMRI} \tag{10.4}$$

and the weighted pipeline time is

$$(1-ERTS)(DP) \tag{10.5}$$

The product of these two terms gives the argument (ARGD) of the following equation. The desired value of Y is the minimum value such that

$$\sum_{n=0}^{Y} \frac{(e^{-ARGD})(ARGD)^n}{n!} \geq CONF \qquad (10.6)$$

This document is one of a series prepared to assist Air Force personnel to understand and apply life cycle costing techniques. Other documents in this series include:

Life Cycle Cost Plan Preparation Guidance, October 1975.

Life Cycle Cost Analysis Guide, November 1975.

Analysis of Available Life Cycle Cost Models and Their Applications, June 1976.

Life Cycle Cost Procurement Guide, July 1976.

Supplemental Life Cycle Costing Program Management Guidance, January 1977.

Copies of all of these documents are available from ASD/ACCX, Wright-Patterson AFB, Ohio 45433.